Introduction

Adaptive agents, intelligence, and emergent human organization: Capturing complexity through agent-based modeling

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Perhaps the most difficult challenge in understanding social phenomena is their intractably complex nature. For much of the 20th century social scientists attempted to unravel the complexities of the social realm by emulating the methodologies of the natural sciences. Although these approaches enhanced social science research, they have fallen short of capturing emergent behavior and self-organization.

For some years now, new approaches to the study of complex adaptive systems have offered researchers in both the physical and social sciences an important new theoretical and methodological framework for helping to understand a variety of nonlinear, dynamic systems. Complex adaptive systems are characterized often by "agents" interacting or capable of interacting with each other in dynamic, often nonlinear and surprising ways. Most social phenomena would readily fit the description of a complex adaptive system. The difficulty researchers have faced, given the opaque character of social processes, is to develop methodologies appropriate for better exploring such complex adaptive systems.

A growing number of social scientists, dissatisfied with traditional methodologies, are seeking new methods for exploring the complexities of social dynamics. One of the emerging developments is the use of agent-based modeling and simulation to examine how social phenomena are created, maintained, and even dissolved. These models, although diverse in their applications and approaches, generally attempt to create "microworlds" or "would-be worlds" (1) in a computer with the goal of determining how the interactions and varied behaviors of individual agents produce structure and pattern. It was this approach to social science modeling and simulation that was the focus of the Arthur M. Sackler Colloquium held at the Arnold and Mabel Beckman Center of the National Academies of Science and Engineering in Irvine, CA from October 4–6, 2001. The title of the colloquium, "Adaptive Agents, Intelligence, and Emergent Human Organization: Capturing Complexity through Agent-Based Modeling," served as a platform for the presentation of numerous papers across a variety of agent-based modeling applications and methods.

Agent-based modeling relies on a novel view of the creation of structure in social systems. Traditional social science generally assumes that social facts such as markets or cooperative behavior exist, and it is they that produce various forms of social organization and structure. Agent-based modeling assumes that both social structure and such social facts as markets or cooperative behavior are created from the bottom up (2) via the interactions of individual agents. Rather than examining how social structure shapes behavior, agent-based modeling focuses on how local interactions among agents serve to create larger and perhaps global social structures and patterns of behavior. Such modeling and simulation approaches allow us to create new worlds from scratch, modifying various conditions and parameters as the need arises. Agent-based modeling thus examines "emergent" behavior as structure and pattern develop from the microlevel interactions. The models ask questions such as "how do markets and cooperative behavior among agents emerge?" Thus, agent-based modeling also can be seen as "generative" social science (3), because the goal is to identify the behavioral and environmental mechanisms that create organization and structure in the human realm.

As with any emerging field, there is considerable diversity in the approaches that can be labeled as agent-based modeling. Some approaches take an evolutionary approach, while others use a more learning-theoretic paradigm. At the core of all such models, however, is a focus on agents interacting on "landscapes" consisting of a two-dimensional grid. Agents are energized by rules that direct their behavior in these landscapes, which potentially can represent the diversity of social environments in which humans interact, bridging the "micro–macro" divide and providing insights into how seemingly simple rules governing agent behavior can produce surprising and unexpected results. The papers presented at this colloquium place agents on landscapes ranging from settlement areas of indigenous peoples to a world of competing nation states to business-organization networks.

The proceedings of the colloquium have been organized into five distinct sections. The first section, *Perspectives*, consists of papers that are commentaries from the chairs of each colloquium panel. These commentaries examine general issues raised by the papers in each panel. The second section, *Economic Agents and Markets as Emergent Phenomena*, presents several papers exploring the emergence of markets under diverse conditions. The third set of papers, *Cooperation and Competition as Factors in Emergent Human Organization*, examines the variety of structures that may result from either cooperative or competitive behavior in both micro- and macrolevel contexts. The fourth group of papers, *Agent-Based Modeling as Organizational and Public Policy Simulators*, reveals the applied side of agent-based modeling by considering the prospects for and applications of these models as organizational and public policy guidance systems. The final section, *Platforms and Methodologies for Enhancing the Social Sciences through Agent-Based Simulation*, provides a view of the field of agent-based modeling and some of the software platforms designed to produce agent-based models.

This paper serves as an introduction to the following papers, which result from the Arthur M. Sackler Colloquium of the National Academy of Sciences, "Adaptive Agents, Intelligence, and Emergent Human Organization: Capturing Complexity through Agent-Based Modeling," held October 4–6, 2001, at the Arnold and Mabel Beckman Center of the National Academies of Science and Engineering in Irvine, CA.

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The relatively embryonic state of agent-based modeling leaves open the future direction of this approach to understanding in the social sciences. Further advances in developing both more user-friendly software platforms and more complex agents and landscapes will serve to enhance this research paradigm and surely will reveal whether agent-based modeling represents a revolution in social science research, as some claim, or a mere incremental evolutionary advance in understanding social dynamics.

We are very thankful to Edward Patte of the National Academy of Sciences for his administrative assistance with the colloquium and to Bridget Coughlin of PNAS for her editorial expertise in producing the journal.

1. Casti, J. (1997) *Would-Be Worlds: How Simulation Is Changing the Frontiers of Science* (Wiley, New York).
2. Epstein, J. M. & Axtell, R. (1996) *Growing Artificial Societies: Social Science from the Bottom Up* (Brookings Institution Press, Washington, DC).
3. Epstein, J. M. (1999) *Complexity* **4** (5), 41–60.